Maturing the M10A 25,000lbf LOX/Methane Broadsword Engine

Completed Technology Project (2017 - 2020)

Project Introduction

Masten's Tipping Point program will advance development of a full-scale additive manufactured aluminum thrust chamber assembly for a 25,000 lbf LOX/LCH4 dual expander propulsion system. Additive manufacturing in combination with an expander cycle LOX/Methane engine enables significantly lower development and production costs over traditional engine manufacturing, while providing the performance and operability necessary for next generation reusable launch vehicles. The dual expander cycle offers an ideal cycle in this size range, enabling reusability, optimal closed loop performance, and very cost effective design and production price points. The two primary focal areas of this technology are: 1) reducing production and assembly complexity through additive manufacturing and scalable systems, and 2) low-cost propulsion systems with design improvements for liquid propulsion systems, use of innovative components manufactured through additive techniques, and suborbital reusable launch vehicles (sRLVs) with aircraft-like VTVL operations. Additive manufacturing processes provide a number of benefits in for increased performance and lower cost. The first benefit comes from a dramatic reduction in part count. Additive manufacturing allows buildup of geometries that would otherwise require an assembly for normal machined parts just to get the tooling into the right places. The second benefit is related but applies to increasing the performance of the engine, additive manufacturing allows for better geometries such as variable cooling channels and more efficient structural shapes. These increase the performance available and decrease the engine weight. A third benefit comes from recent advances in materials science in the area of metal matrix composites which allow us to tailor the material properties for such things as thermal conductivity and high temperature strength. The use of a dual expander cycle, with both the oxygen and methane heated in the cooling jacket and fed into independent turbopumps, will contribute to the lower cost and higher reusability of the engine. Using methane and oxygen in an expander cycle provides a very benign environment to the turbomachinery. In an expander cycle the temperature of the gasses as they pass through the turbine are moderate and do not require any special materials or coatings on the turbine. Also, the gasses are clean and do not leave a soot buildup. These two facts make the turbomachinery inherently reusable, which lowers operational costs, and since no special materials or coatings are required, the components can be made less expensively. Masten will use this engine, designated M10A Broadsword, as the main propulsion for both the booster and upper-stage of a two-stage VTVL small launch vehicle system, which is capable of inserting up to 250 kg spacecraft into a variety of orbits including lower earth orbit (LEO), and sun-synchronous orbits (~98° inclination) at altitudes up to 900km. Larger variants of the Broadsword family also support Masten's VTVL medium class launch vehicle, providing up to 1,500kg to LEO. The inherent flexibility of this engine design allows for use in boost and upper-stage variants for reusable and expendable launch vehicles, modular clusters, and as options for larger and smaller scale LOX/methane engines. Additionally, this engine

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design and development can be applied as crosscutting technology in modifications towards other cryogenic (LOX/LH2) propellant systems, liquid cryogenic in-space propulsion, and in-situ resource utilization on Mars.

Anticipated Benefits

Additive manufacturing processes provide a number of benefits in for increased performance and lower cost. The first benefit comes from a dramatic reduction in part count. Additive manufacturing allows buildup of geometries that would otherwise require an assembly for normal machined parts just to get the tooling into the right places. The second benefit is related but applies to increasing the performance of the engine, additive manufacturing allows for better geometries such as variable cooling channels and more efficient structural shapes. These increase the performance available and decrease the engine weight. A third benefit comes from recent advances in materials science in the area of metal matrix composites which allow us to tailor the material properties for such things as thermal conductivity and high temperature strength. The inherent flexibility of this engine design allows for use in boost and upper-stage variants for reusable and e1pendable launch vehicles, modular clusters, and as options for larger and smaller scale LOX/methane engines. Additionally, this engine design and development can be applied as crosscutting technology in modifications towards other cryogenic (LOX/LH2) propellant systems, liquid cryogenic in-space propulsion, and in-situ resource utilization on Mars. These solicitations increase focus on collaborations with the commercial space sector that not only leverage emerging markets and capabilities to meet NASA's strategic goals, but also focus on industry needs. NASA's investments in industry partnerships can accelerate the availability of, and reduce costs for the development and infusion of, these emerging space system capabilities. While developing the technology to enable NASA's next generation of science and human exploration missions, we will grow the economy and strengthen the nation's economic competitiveness.

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Masten Space Systems, Inc

Responsible Program:

Flight Opportunities

Project Management

Program Director:

Christopher E Baker

Program Manager:

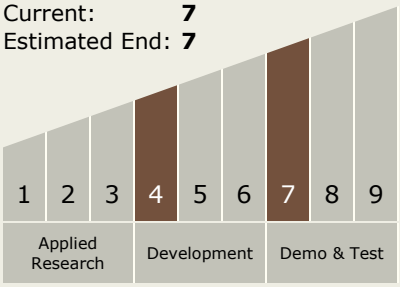
John W Kelly

Principal Investigator:

Matthew Kuhns

Technology Maturity (TRL)

Start: **4**
Current: **7**
Estimated End: **7**



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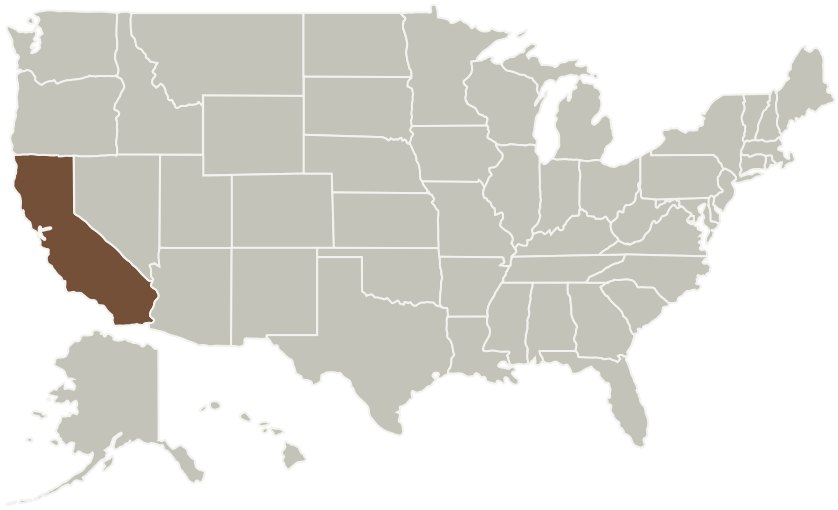
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Masten Space Systems, Inc	Lead Organization	Industry	Mojave, California

Primary U.S. Work Locations
California

Project Transitions

June 2017: Project Start

February 2020: Closed out

Closeout Summary: Masten Space Systems is developing an engine that incor porates advanced manufacturing techniques. The engine will be used to provide a lower-cost reusable launch service for the growing CubeSat and smallsat launc h market. The engine was successfully tested at the AFRL facility at Edwards AF B in the fall of 2019.

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Target Destination

Earth